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Peer tutoring in conceptual design

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A peer tutoring scheme has been introduced into the Department of Engineering at the University of Liverpool to help 2nd year undergraduate students tackle conceptual design problems. Conceptual design is an iterative process consisting of a series of generative and evaluative stages, which gradually converge on a preferred conceptual solution. Students are generally less comfortable with the task of generating, evaluating and presenting ideas and this leaves them less able to tackle a conceptual design project without the help and intervention of available teachers or experts. Formally, the students were taught through lectures, coursework and critique sessions. Peer tutors were trained to facilitate group sessions whereby the students were able to discuss ideas, evaluate new concepts, generate solutions and learn to communicate more effectively within a non-threatening environment. The students developed problem-solving skills, became more confident and took more responsibility for their own learning. The peer tutoring process also had a positive effect on the tutors, who felt they had become more responsible and employable, improved their communication and leadership skills and deepened their own understanding of design, as a result of the peer tutoring experience.

Keywords: Peer tutoring; Conceptual design; Group learning; Communication; Problem solving

1. Introduction

Peer tutoring schemes currently operate in many different countries and disciplines worldwide to promote student learning (Baillie 1998, Baillie and Grimes 1999). The aim of peer tutoring is to facilitate student learning by making the group work for itself, without providing supplementary teaching or textbook solutions to set problems. Peer tutors help junior students by holding group sessions and acting as a focus for the group. The group provides a non-threatening, supportive learning environment for the students, which allows them to develop their ideas when solving particular problems and test out their understanding of difficult concepts. Peer tutoring promotes a deeper approach to learning and encourages students to take more responsibility for their own learning. In the process, the students also gain confidence and develop key skills such as communication, problem-solving and group-working.

In design, students must start by defining the problem they are to solve, and then go on to use their basic knowledge of materials, manufacturing and engineering principles to create a solution to the problem. This is usually referred to as the design process and normally consists

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of a product specification, conceptual design phase and detailed design phase. Students are usually more able at solving problems that are already defined for them and are generally less comfortable with the task of generating, evaluating and presenting ideas. This leaves them less able to tackle a conceptual design project without the help and intervention of available teachers or experts. With reduction in staff involvement in design teaching and the introduction of a new design module, there was an opportunity to develop a peer-tutoring scheme to promote student learning where it should readily be put to the test. In the Department of Engineering at the University of Liverpool, a peer-tutoring scheme was established in January 2003 for second year design students, and focused on conceptual design and the development of design skills. Although conceptual design is an important activity in the design process, it is often underestimated or even overlooked by students and at best given inadequate attention. In general, there seems to be poor understanding by engineering students of the role, importance and activities of the phase. This is generally reflected in the curriculum that perhaps places more emphasis on engineering analysis and less on the creativity of engineering design. The conceptual design phase demands a skill to think in an innovative and creative manner. The principles of peer tutoring were considered appropriate for the development of these creative design skills in students and the fostering of a non-threatening forum for generating and evaluating ideas and concepts. The students would feel more comfortable to express their views and share their ideas amongst themselves in a small-group situation as facilitated by the peer tutor.

2. Elements of peer tutoring

Certain elements are considered to be essential to the practice and principles of peer tutoring, and are shown in table 1. These include elements of training for tutors, group focus, voluntary attendance and evaluation mechanisms.

3. Implementing the scheme

3.1 *Peer tutoring*

Baillie (1998) recommends that certain conditions, related to departmental commitment, budgetary requirements and evaluation, be met for successful implementation. In practice,

Table 1. Key elements of an idealised peer-tutoring scheme.

Training	A training day is necessary for each tutor to learn effective small group tutoring and facilitation methods
Attendance	Voluntary and confidential
Focus	Students in the group to ask and answer questions, generate and evaluate ideas, with the focus maintained by the tutor (facilitator)
Evaluation	On-going evaluation of the effectiveness of the scheme
Group sessions	Usually one session every week or every 2 weeks, with a student/tutor ratio between 5 and 10
Feedback	Through questionnaire, focus groups, informal discussions
Student benefits	Mastery of concepts, development of key skills, safe working environment, more responsible attitude towards learning, enables team-working, builds confidence, increases performance levels, develops relationships with students in other years
Tutor benefits	Develops leadership skills, allows tutors to practice their subject, reinforces their own learning, more responsible attitude to learning, provides valuable training and experience, makes them more employable, develops their confidence

compromises have to be made (Baillie 1999) and a more realistic set of conditions was formulated for the present scheme. These included the support of lecturers who are willing to try the scheme, the use of a scheme administrator (to recruit and train tutors, liase between peer tutors and subject lecturers, carry out daily administration and collate evaluation material) and obtaining the support from the head of department. Other vital elements included maintaining good communication between the peer tutors, subject lecturers and scheme administrator, running an evaluation scheme (to assess the effectiveness of the peer-tutor programme) and a feedback mechanism (to other staff in the department so they can see it is worthwhile). Advice from others more familiar with peer tutoring was sought (provided by the UK Centre for Materials Education) and a pilot scheme was implemented and evaluated.

This paper reports on the implementation of the pilot scheme and the evaluation results. The following perceived needs were highlighted:

- Lack of staff time for extra tutorials and decreasing staff involvement in design teaching;
- Difficulties students found with design, particularly in defining the problem and formulating original solutions;
- Development of key skills in the students, particularly group-working, communication and problem solving.

The objective was to introduce a peer-tutoring scheme in an engineering design module. This would enable students to work through and think out a design problem for themselves and give more experienced students (acting as tutors) an opportunity to develop their own leadership skills and be involved in the learning process. Other objectives included the evaluation of the scheme and dissemination of the results.

3.2 *Conceptual design*

Good conceptual design is the key to producing distinctive and innovative products. This is best achieved through:

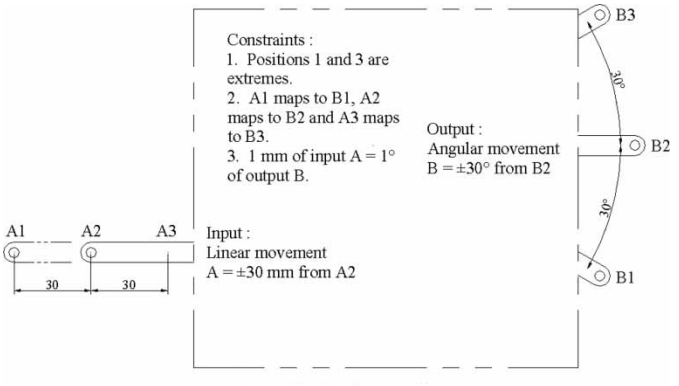
- Team-working;
- The use of appropriate tools and techniques;
- Generating an extensive range of concepts;
- Evaluating all concepts systematically against the design specification;
- Preventing the adoption of a particular solution early in the process without systematic evaluation.

Conceptual design is an iterative process consisting of a series of generative and evaluative stages, which gradually converge on a preferred conceptual solution. Concept generation involves the development of whole product or sub-system concepts. These are normally presented in the form of sketches, layout drawings or diagrams. There are a number of methods that can be used to provide a focus and catalyst for concept generation and can also provide a much-needed structure to the activity. Many of these are particularly compatible with peer tutoring principles and use a team-based environment. Brainstorming, which is a problem solving activity undertaken by a multi-disciplinary group, was thought to be most appropriate for the peer-tutoring scheme. The group meets specifically to generate ideas aimed at solving a stated problem (Chaplin 1989, Pugh 1991).

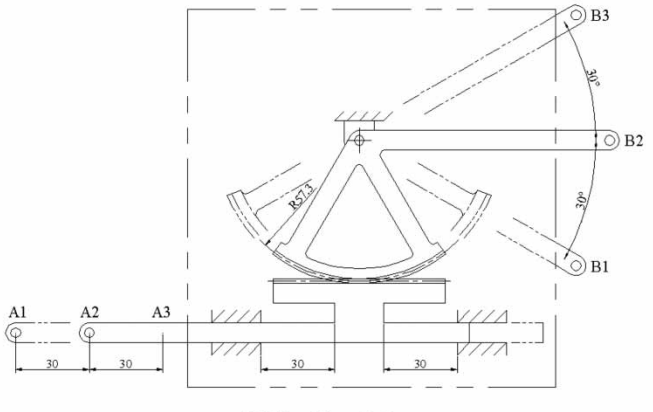
Peer tutoring was implemented to assist with a new Conceptual Design module taught to Year 2 undergraduates from Mechanical Engineering, Integrated Engineering, Materials and Manufacturing, Clinical Engineering and Manufacturing Systems programmes. Formal lectures were given during the first 4 weeks of the semester, introducing students to basic

engineering components (for example bolts, springs, beams), mechanisms (for example levers, gears, cams and followers) and fastening methods. Other lectures on schematic drawing, problem solving and communication were also included. The first design problem was given out, and consisted of a 'black-box' exercise – the students were given various input/output constraints and geometry considerations (product specification), and were instructed to fill the 'black-box' with a mechanism design which met the design criteria. A typical 'black box' problem and a possible solution are shown in figure 1.

Peer tutor sessions were used in brainstorming mode to define the problem, generate ideas, discuss possible solutions, evaluate students' designs and talk through possible industrial applications. A comfortable, non-threatening atmosphere, where ideas could be discussed without fear of intimidation or ridicule, was promoted and encouraged by the peer tutor sessions. Solutions, in the form of schematic drawings, were submitted and a formal design critique lecture was given to provide feedback to students on the strengths and weaknesses of their design approaches, and highlight any deficiencies in their drawing techniques or problem definition. The next exercise was given out and the process continued until the students had completed three design problems. The students were then instructed to produce a manufacturing drawing of one of their design components, and write a short report on a possible industrial application of one of their designs. Each student also gave an oral presentation on the subject of his or her report. The group sessions in most cases had finished by that stage, but one group continued



(a) Typical design problem



(b) Possible solution

Figure 1. Example of a 'black box' design problem and one possible solution.

to provide support during the report writing process, at the request of the students. There were a total of 7 tutor groups, with 7 or 8 students in each. Students were selected for groups based on their undergraduate programme to enable easier timetabling of the sessions with the tutor.

4. Peer tutor training

Peer tutor training is fundamental to the scheme, as it has been shown that the tutees of trained tutors can perform significantly better than those of untrained tutors. Most peer tutor training courses are generic in nature, and the subjects considered in role-playing situations have little in common with the subjects that will be tutored. In cases where an engineering student has to tutor a difficult technical subject, no confidence is gained from discussions on, for example, a humanities-based tutorial 'game'. Student tutors may find it difficult to bridge the gap between the training course and the real task, and often 'switch-off' during training because they perceive it as irrelevant. A similar phenomenon often causes problems in postgraduate training and staff development courses.

The training course in the Engineering Department aimed to help the prospective tutors to understand the need to facilitate the learning process rather than to teach the subjects. Training included sessions on different learning approaches (surface, deep and strategic learning), ice-breakers, setting up ground rules, how to start off, session strategies, how to help students think creatively and how to re-direct questions. The prospective tutors explored good group practice techniques, for example probing, brainstorming, monitoring group dynamics, developing listening skills, closing techniques and working in pairs/threes/larger groups.

An experiential learning approach was adopted in the tutor training, where students all took a turn to role-play the tutor and students in a scenario with 'problem students' (such as dealing with silence, dissent or over-zealous/dominating people). Ideas and experiences were brainstormed, and possible solutions were discussed. These were put into practice in the next simulated tutorial.

To engage the students' attention and develop their confidence in tutoring, 'real' design problems were used in context. 'Black-box' exercises, similar to those used in the lectures, were solved in the simulated tutorials. In one tutorial session, the prospective tutors were tasked with developing their own 'black-box' exercise. The students all agreed that the training had been a useful and enjoyable experience. After training, the peer tutors felt more confident and better equipped.

5. Evaluation

5.1 *Evaluation strategy*

The pilot scheme was run throughout the second semester of the 2002/2003 academic year. Sessions were held weekly from weeks 4 to 11, although attendance at the groups suggested that holding the sessions once per fortnight might be more profitable. The pilot scheme was launched late in the academic year, and resulted in some timetabling difficulties that have now been resolved for future years. The scheme administrator liased between the tutors, and also reported on room changes and dealt with other difficulties. The tutors were given a set of course notes (the subject content was new for that academic year) and in most cases, advanced copies of the design exercises. They were not supplied with typical solutions as this may have resulted in the tutors leading the group in a particular direction.

In order to evaluate the scheme, coursework marks, attendance at lectures, attendance at tutorials and the perceptions of those involved were recorded. Student perceptions of the peer-tutoring scheme were obtained through use of a dedicated questionnaire. The subject lecturers' perceptions were obtained through informal discussion and the tutor perceptions by a focus group session with the tutors (facilitated by the administrator). All of this information was collated and analysed.

5.2 *Student perceptions*

Student feedback of the peer-tutoring scheme was obtained through an anonymous questionnaire. The questionnaire consisted of six open ended questions that asked what the students had gained from participating, what could be improved and what aspect of the tutors teaching methods they found particularly effective. About 70% of the students responded with their comments. Some students mentioned problems with attendance and timetabling, which can be addressed in future years. Despite these problems, most students felt that the peer-tutoring scheme had been a positive experience. Some students commented that the scheme had led them to form their own informal discussion groups.

Figures 2 and 3 contain student responses to the questions, 'what do you feel you have gained from the peer tutoring scheme?' and 'what teaching methods of the tutor did you find most effective?' Figure 2 shows that a small number of students failed to gain anything from the experience, but it is most likely that these did not attend the tutorials. Most felt they had gained by discussing the problems; they noted increased generation of new ideas and improved group-working skills, among other benefits. The students identified several different teaching methods used by the peer tutors, which have been grouped into seven categories, as shown in figure 3. The students felt that the most effective teaching methods were facilitation of group discussions and getting them to share and explain their own ideas. Other methods included board work, brainstorming, sketch drawing and dividing the group into smaller numbers for

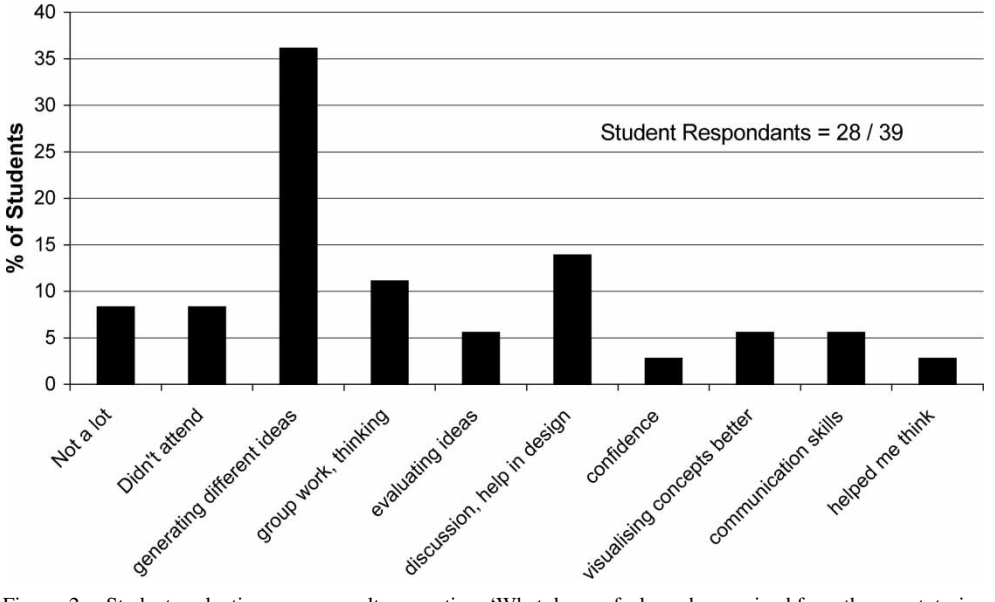


Figure 2. Student evaluation survey results – question: 'What do you feel you have gained from the peer tutoring scheme?'.

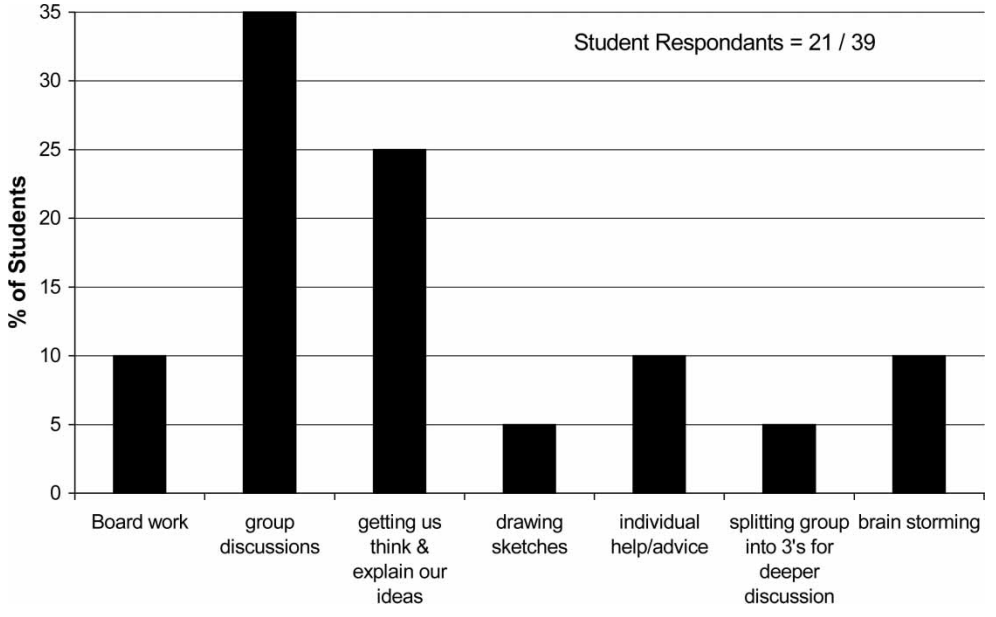


Figure 3. Student evaluation survey results – question: 'What teaching methods of the tutor did you find most effective?'.

more in depth discussions. Peer tutoring is a particularly cost-effective and beneficial way of achieving this kind of interaction between students.

5.3 *Peer tutor perceptions*

The peer tutors were evaluated by a focus group in which tutors were asked to focus on the process and content of the students' learning, on the benefits of the course to their own development and ways in which future groups could be improved. All of the tutors felt the experience had been a positive one, and would definitely take part again if given an opportunity in the future. Their responses are shown in table 2.

5.4 *Lecturer perceptions*

Informal discussions between the subject lecturers and the scheme administrator suggest that the scheme has been well integrated into the module design and intended learning outcomes. From the attendance records kept by the tutors, and the students' own perceptions of their attendance, it appeared that 50% of the students attended most of the tutorials with some tailing-off towards the end. A couple of the tutorial groups were less well attended, mainly due to the timetabling problems mentioned above. The lecturers commented that the peer-tutoring scheme encouraged self-learning and maturing of the students and took some of the pressure off academic staff. They also felt that weaker students in the groups would learn from stronger, more mature students, equipping them with improved design skills. This process was not detrimental to the stronger students, who gained from explaining their designs and ideas to their peers.

Table 2. Peer tutor perceptions.

(1) What happened in the tutorials?
The students discussed different ways of solving the problems
Students worked on the white boards
Students worked in small groups and came back together for full group discussions
They explained their designs to each other and to the tutor
They thought more about their designs
They asked questions about what the course was like in later years
Groups met informally outside of the timetabled slot at the students' request
(2) Did the students change their approach to design after the groups?
Students became more willing to participate
They evaluated and checked their own designs more, and those of other group members
They became less dependent on the tutor for ideas and input
More ideas were suggested during brain storming sessions
(3) What could be improved?
Some timetabling difficulties with rooms/free time
Some language problems with foreign students
Having the group sessions nearer to the formal design lecture times
(4) How did they benefit from being a tutor?
Learned a lot about conceptual design and mechanisms
Improved communication skills
Deeper relationships with second years
Enjoyed the group sessions
Skills learnt helped them become more employable
Became more responsible, helping others in the learning process

5.5 *Coursework marks*

Table 3 shows the average marks awarded to students in each peer tutor group for the three design exercises. Overall performance (all groups) from exercise 1 to exercise 3 was 68.7%, 73.7% and 72.1%, respectively. The coursework marks improved from exercise 1 to exercise 2, indicating that the students were becoming more capable of defining and solving engineering design problems, although with the course being a new one, it is not clear whether the peer tutoring sessions or the critique lectures were responsible for this. It is suggested that both elements played an important role in improving the student performance, and that this could be built upon in the future and expanded to other subjects taught within engineering. It is also suggested that the marks for exercise 3 were slightly lower due to the increased difficulty of the problem. Improvements in overall performance compared with 1st semester marks (no peer tutoring) were noted, with the average mark increasing from 62% to 67.2%, a rise of over 5%.

Table 3. Evaluation of student performance during the conceptual design course.

Group no.	Marks per exercise (%)			Average lecture attendance (%)	Total average mark (%)
	1	2	3		
Group averages					
1	77	75	80	90	74
2	51	71	67	80	63
3	69	75	76	90	69
4	70	74	65	80	68
5	67	72	63	70	64
6	77	82	60	90	68
7	57	66	61	80	62
Average (all students)	68.7	73.7	72.1	80	67.2

Attendance at lectures was good, with 80% average attendance. It is interesting to note that individual students with poor attendance at lectures were linked to lower than average overall performance.

6. Future years

A peer tutoring pilot scheme has been implemented and a number of observations were made during the year. For the scheme to be run in future years, a free slot in the timetable immediately following the formal lectures must be assigned for the peer tutoring sessions in all Year 2, 3 and 4 timetables, ensuring at least one mutually convenient hour per week when the tutors and tutees would be free to meet. It would also be helpful to identify early those tutors who attract less students to their groups and provide them with additional support to establish their groups. Once established as a regular feature in the engineering courses, a tutor representative could be appointed from the previous years' recruits, whom the tutors would feel comfortable talking to when issues or problems arose. The representative would be able to share their experiences in discussions regarding the use of peer tutoring in the future.

7. Conclusions

The pilot peer-tutoring scheme in the Department of Engineering at the University of Liverpool has been successfully implemented within a conceptual design module. It appears to have been effective at enabling students to take more responsibility for their own learning, promoting creative problem solving and developing group-working skills. There has also been a significant benefit for the tutors themselves, who developed additional team-working and leadership skills, as well as growing in confidence and developing a more responsible attitude towards learning. The peer tutoring approach can be implemented with minimal financial cost or staff time, aside from the initial training of the tutors.

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Graham Schleyer (BSc, PhD, CEng, MIMechE) is a chartered mechanical engineer with 20 years' experience covering onshore and offshore structures, coal mining equipment and large

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Simon James (BEng, MScEng, PhD, CEng, MIMechE) was born in Cheltenham in 1946. He joined the Merchant Navy (Elder Dempster Lines) in 1963 and served a 5-year apprenticeship as a cadet engineer officer. In 1968 he worked for David Bridge & Co. of Rochdale as assistant works engineer. He studied Mechanical Engineering at Liverpool University from 1970, gained a B.Eng degree in 1973 and a Secondary Education Teaching Certificate in 1974. He joined United Towing (Marine Services) in Hull in 1974 as design engineer and in 1976 was promoted to salvage superintendent. In 1980 he became a senior experimental officer at Liverpool University (Mechanical Engineering), gained an MSc.Eng in 1990 on combined loading of ring stiffened cylindrical shells and a PhD in 2003 on disc brake squeal. Currently, as principal experimental officer, his research interests are primarily in structural modal analysis. He is also involved in undergraduate teaching of engineering design.

Genevieve Langdon (MEng, PhD) joined the University of Liverpool in 1999. She was employed as a researcher within the Impact Research Centre for five years, and is now a research fellow at the Blast Impact and Survivability Research Unit (University of Cape Town). Her research expertise is concerned with the response of structures and materials to extreme loading events, with a special interest in blast loading response. She has a keen interest in novel teaching methods and recently organized the peer-tutoring scheme within the Engineering Department at the University of Liverpool.